Characterization of Encapsulated Corrosion Inhibitors for Environmentally Friendly Smart Coatings

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Benjamin P. Pearman, Wenyan Li, Jerry W. Buhrow, Xuejun Zhang, Marissa N. Johnsey, Jan M. Surma, Lilliana Fitzpatrick, Eliza L. Montgomery and Luz M. Calle

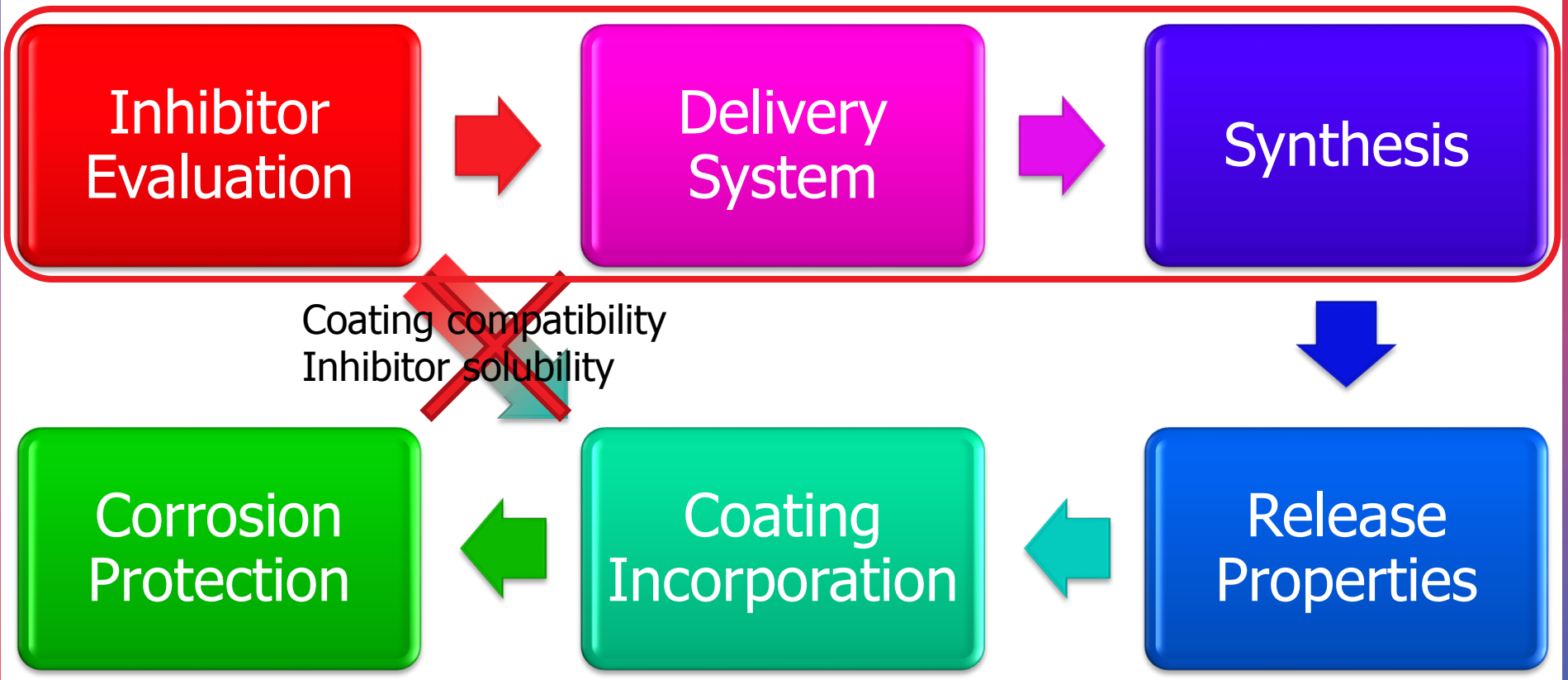
NASA, Kennedy Space Center, Corrosion Technology Laboratory

Corrosion

- Cost: World: $2.2 tr (2010); US : ~$1 tr (2013)
- Safety concerns
- Replace current corrosion inhibitors with environmentally friendly alternatives
  - Coating compatibility issues
  - Solubility issues

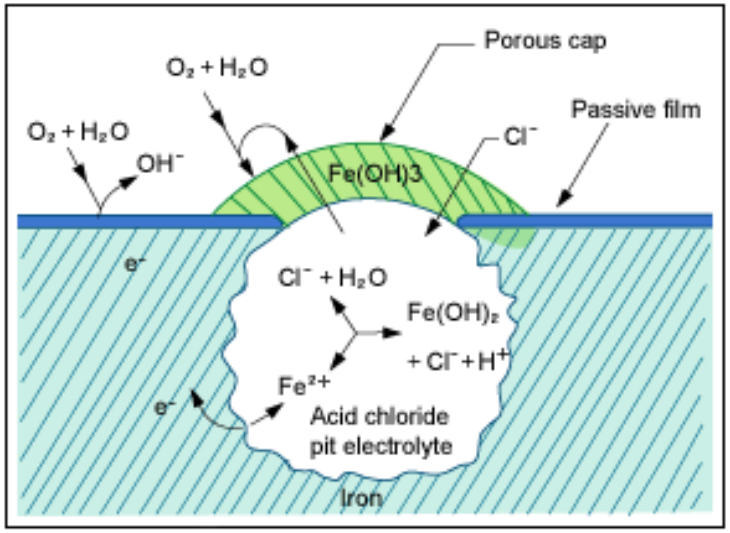
World Corrosion Organization 2010

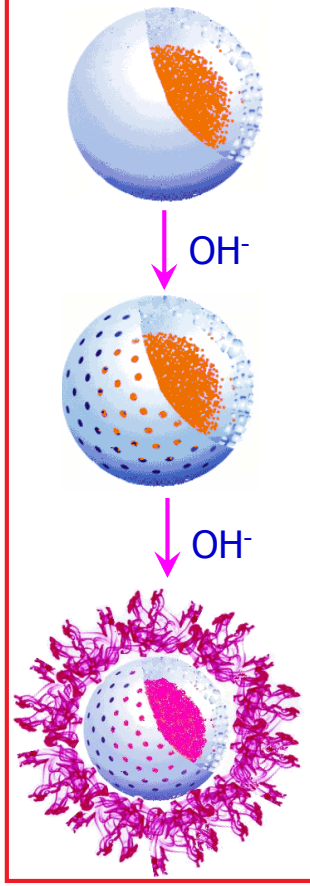
Delivery System



KSC Delivery System

- "Smart coating" for corrosion sensing and control
  - Autonomous
  - Corrosion triggered
  - Versatile





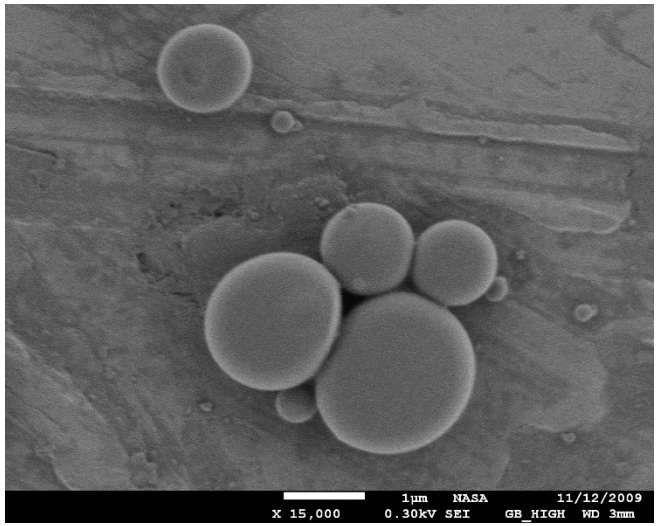
Microcontainer containing pH indicator, inhibitor or self healing agents

The shell of the microcontainer breaks down under basic pH (corrosion) conditions

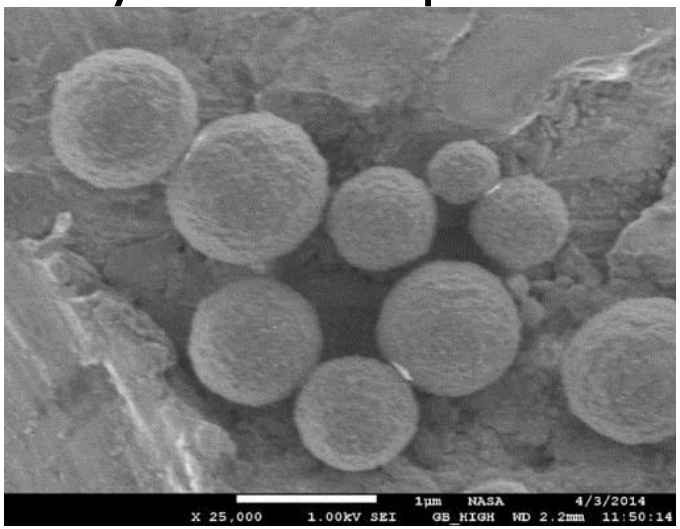
Contents is released from the microcontainer when corrosion starts

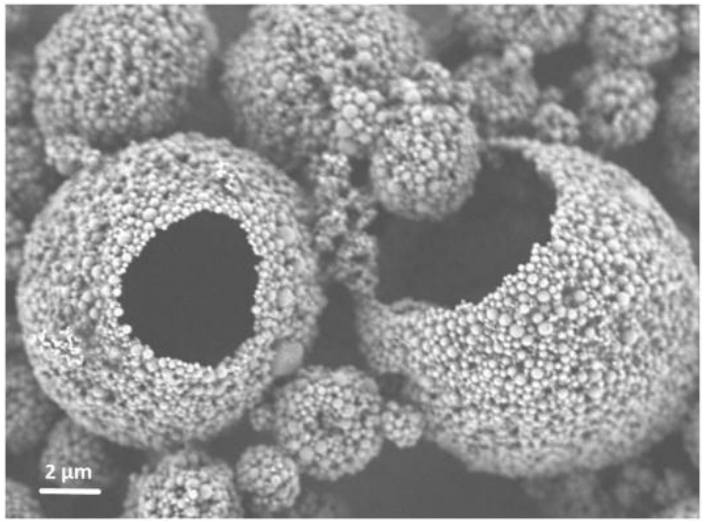
Microcontainers

Polymer Microcapsules



Polymer Microparticles



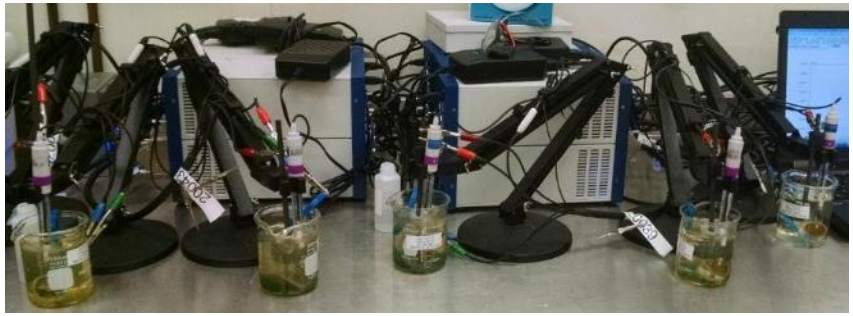


Inorganic microparticles

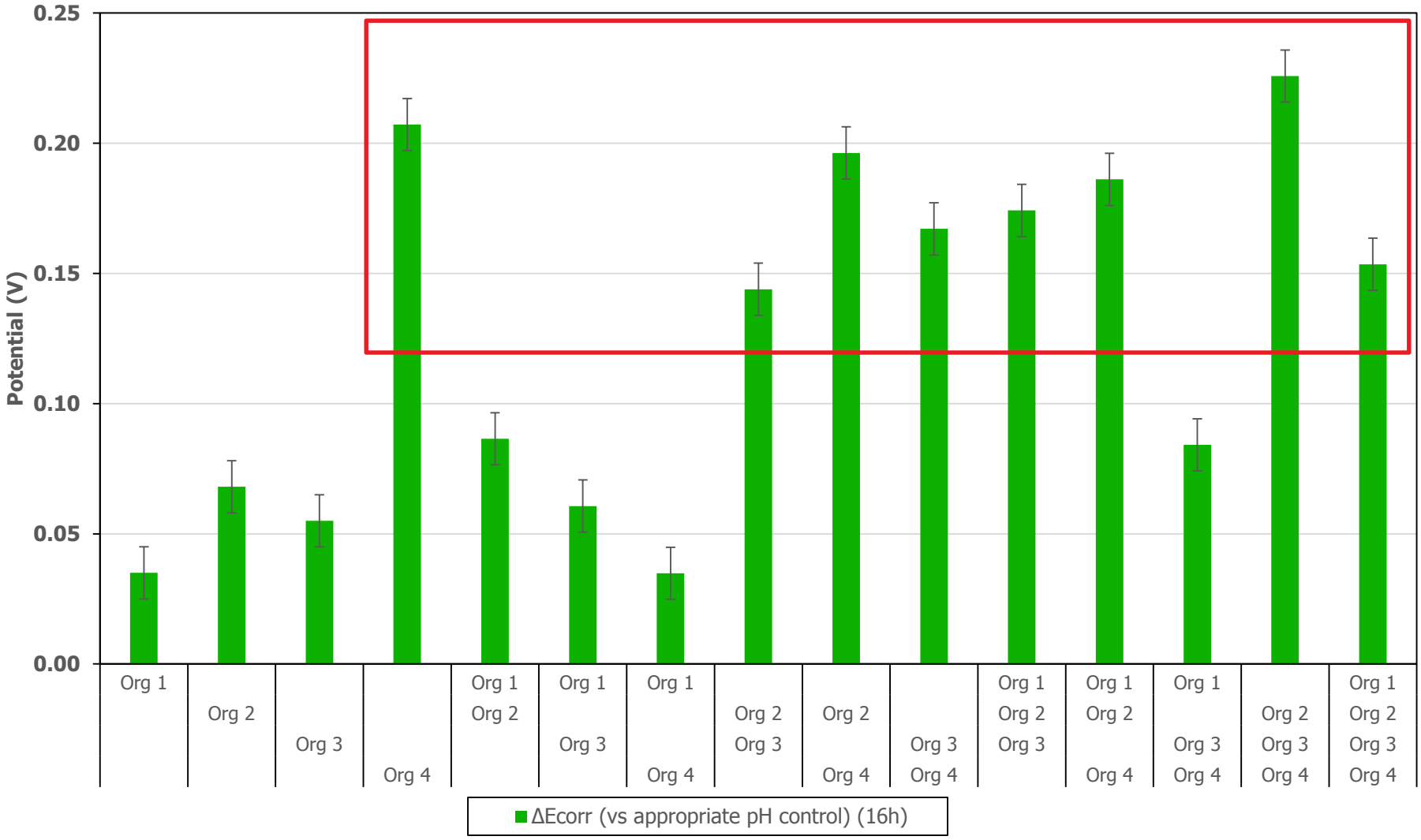
Free flowing powder

Inhibitor Evaluation

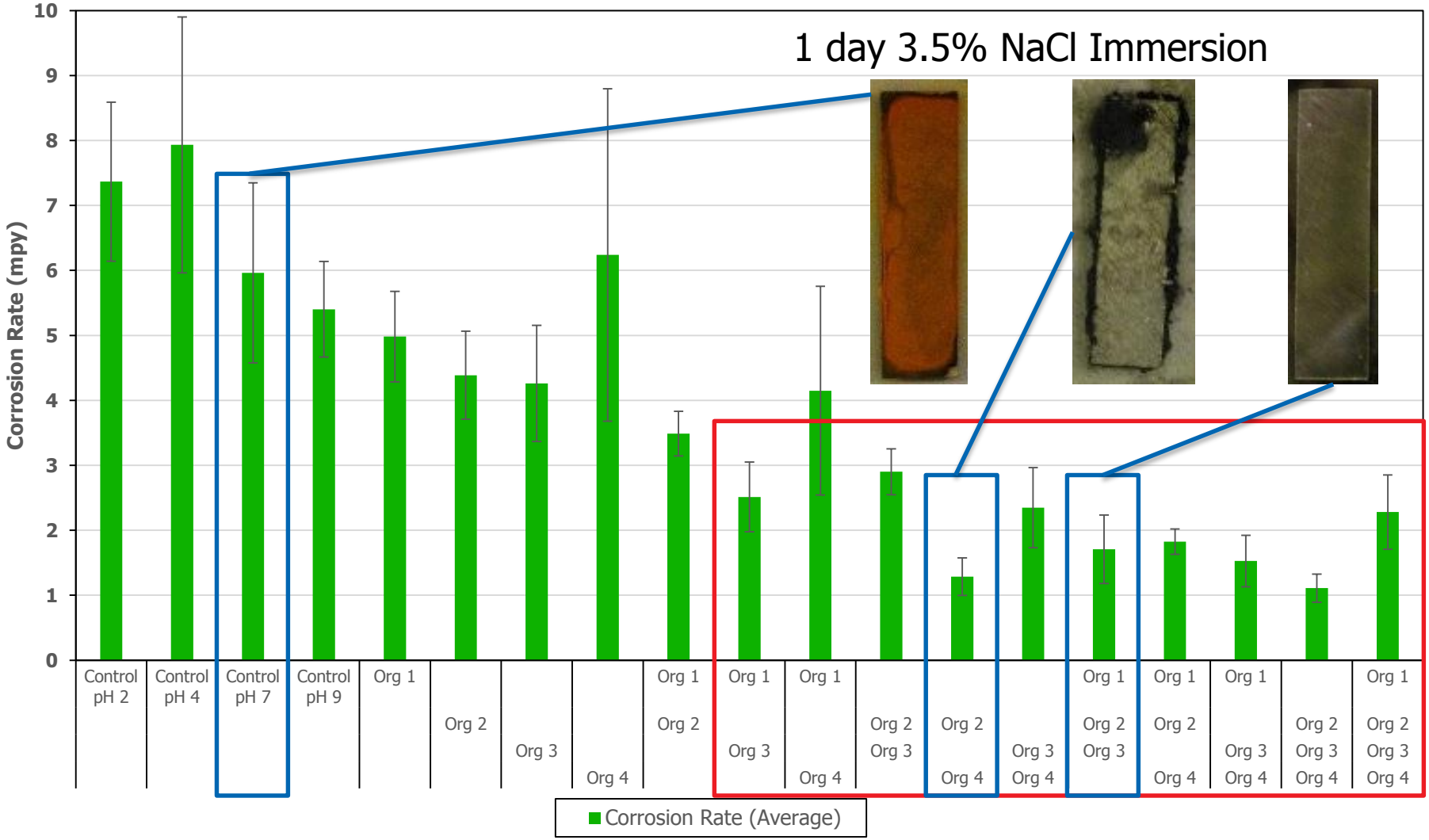
- Electrochemical measurements
- Salt immersion
- Carbon steel in 3.5% NaCl solution
  - Organic inhibitor 1 (Org 1)
  - Organic Inhibitor 2 (Org 2)
  - Organic Inhibitor 3 (Org 3)
  - Organic Inhibitor 4 (Org 4)



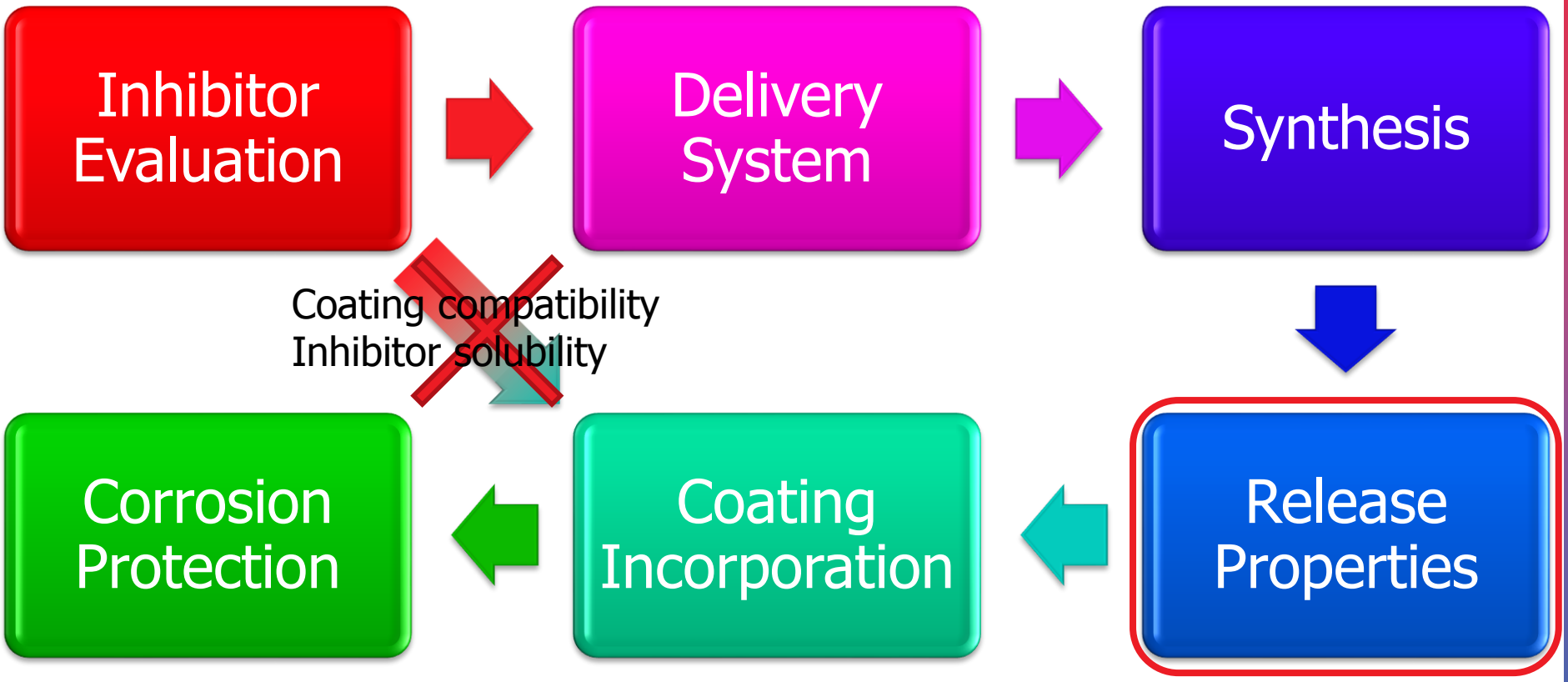
Corrosion Potential Increase



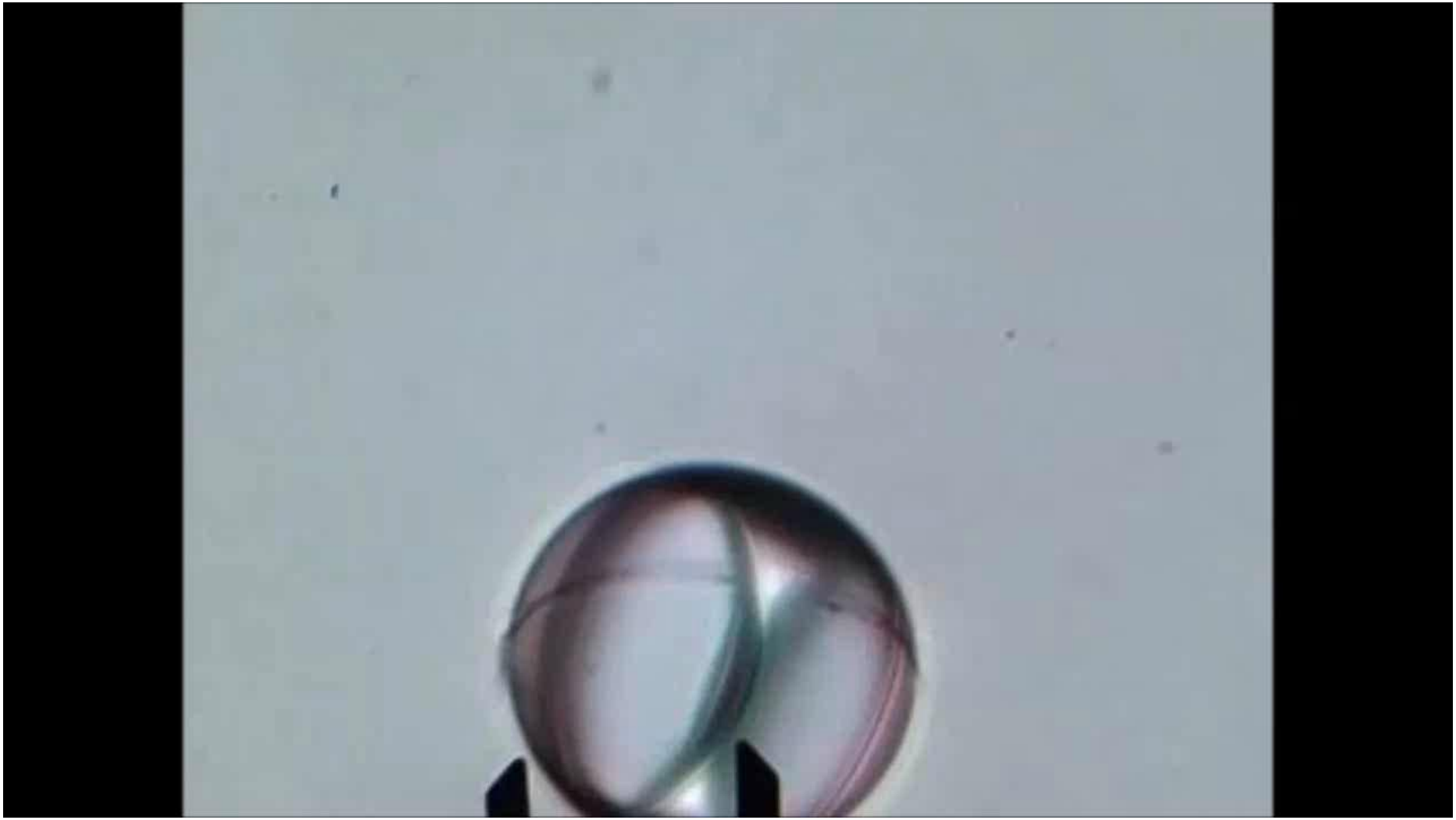
Corrosion Rate



Delivery System



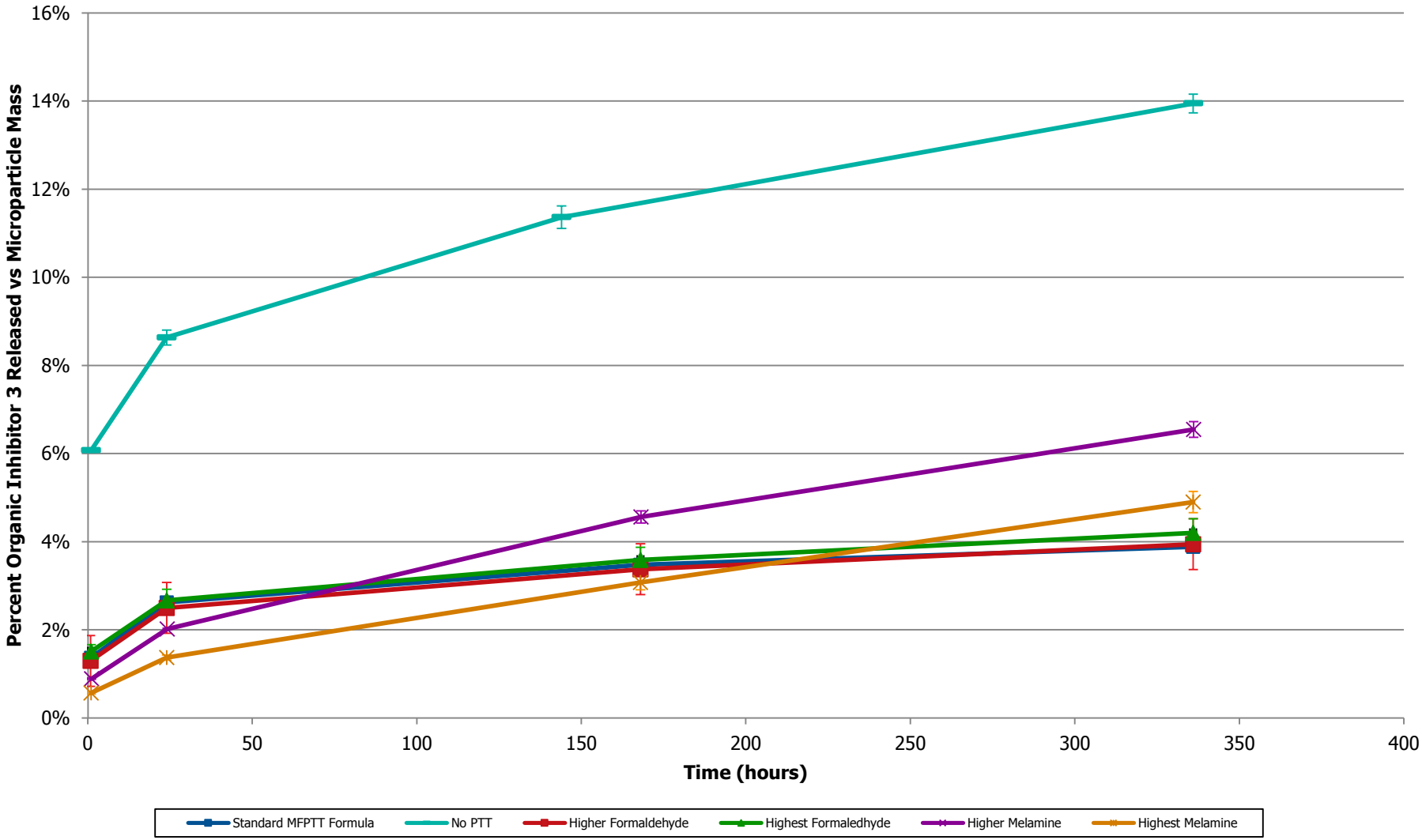
pH-Triggered Release of Corrosion Indicator



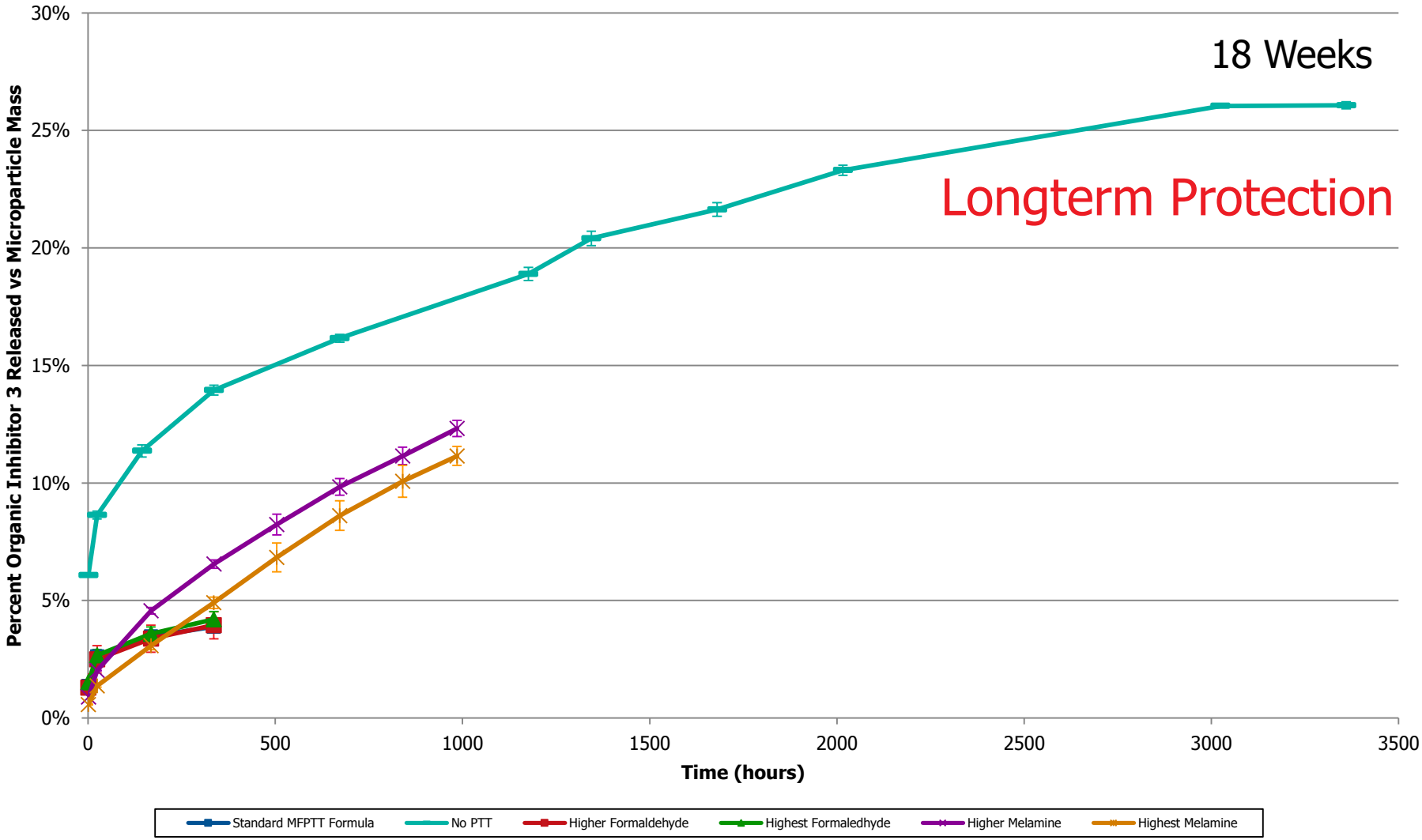
Inhibitor Release

- Determine release of inhibitor with time
  - Organic: Melamine-formaldehyde-based polymer
  - Inorganic: Silica-based particles
  - Organic Inhibitor 3 (Org 3)
  - Inorganic Inhibitor 1 (Inorg 1)
  - Inorganic Inhibitor 2 (Inorg 2)
- Method
  - Immersion of particles into 0.01 M base
  - Sampling at regular intervals

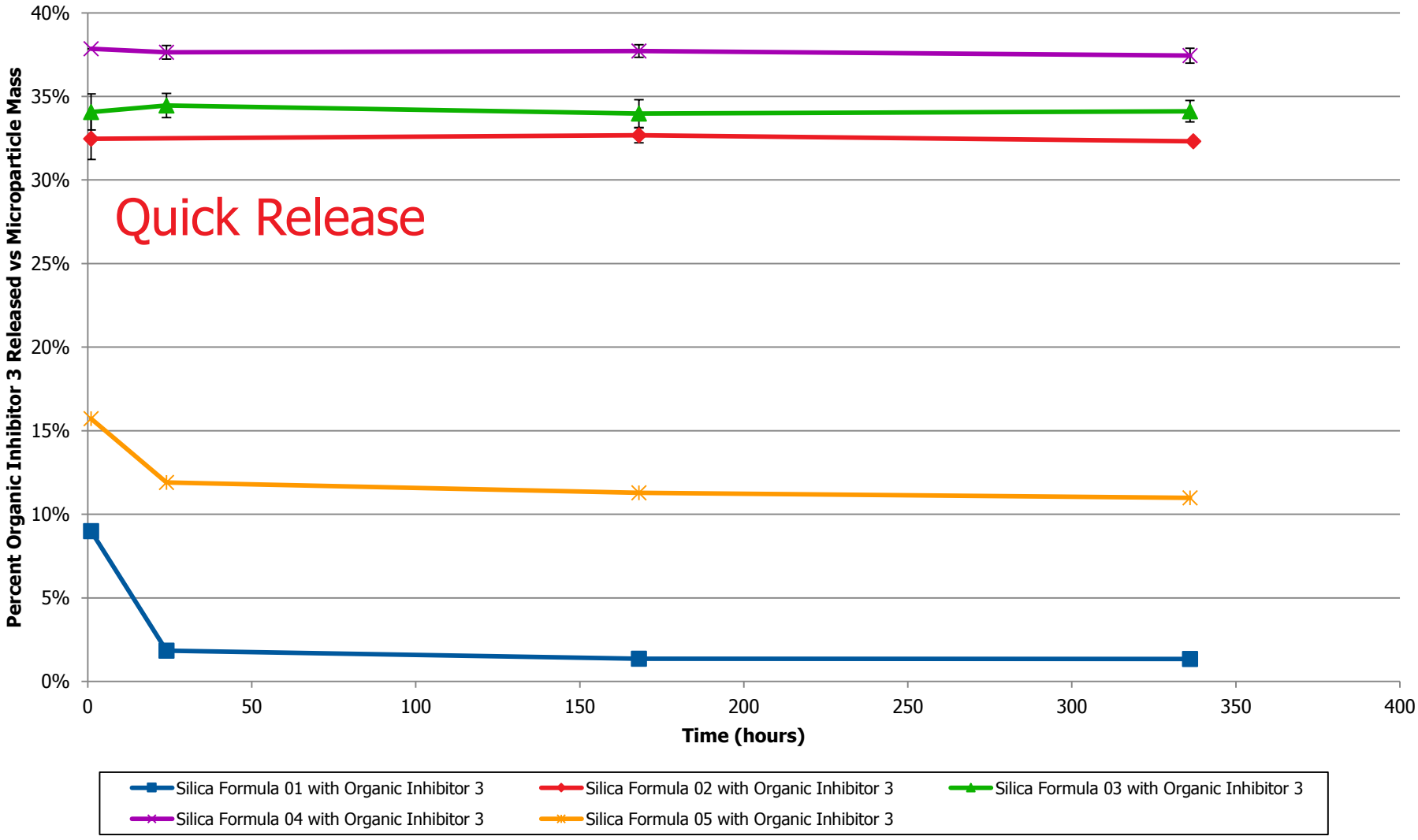
Organic: Short-Term Release



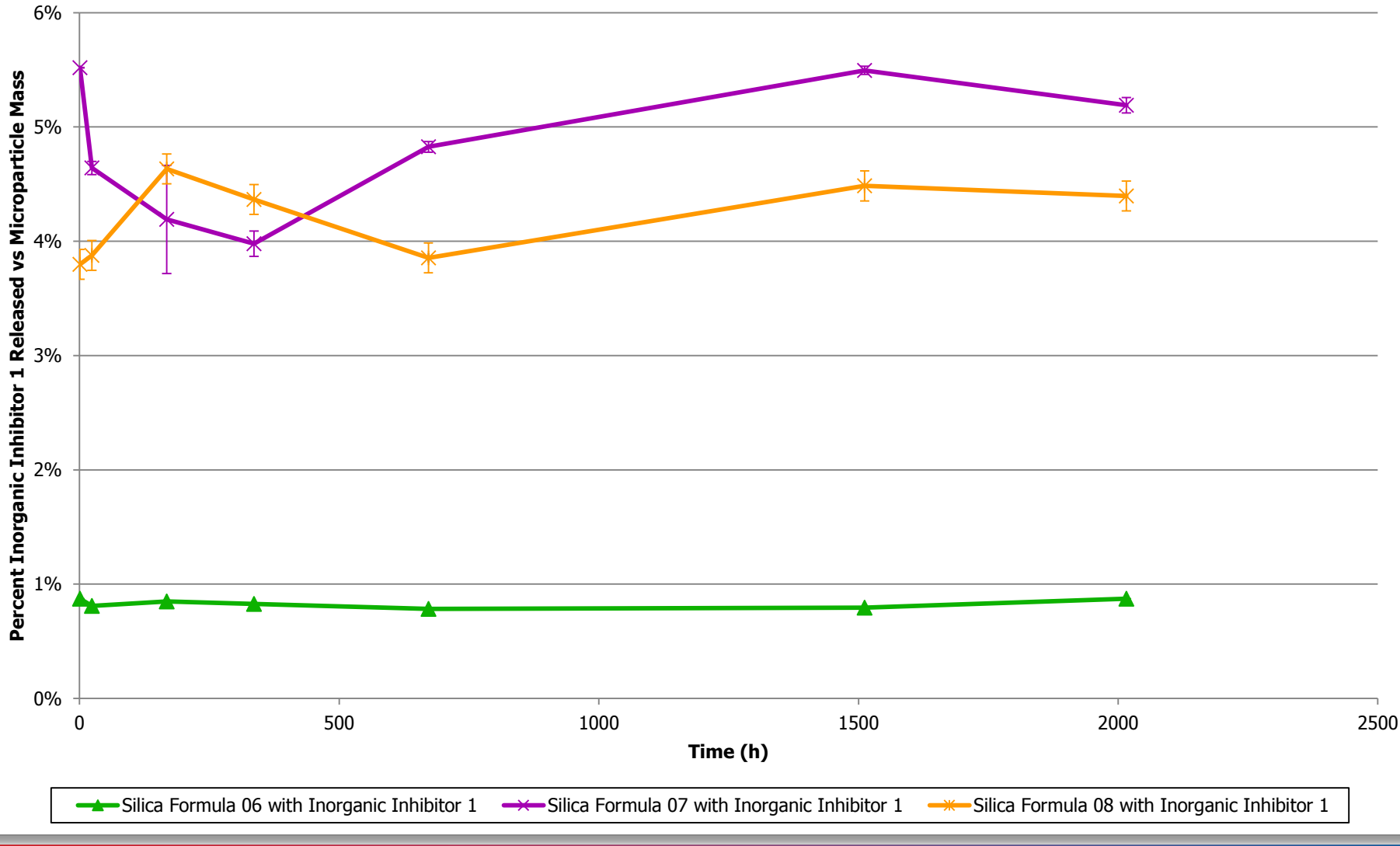
Organic: Long-Term Release



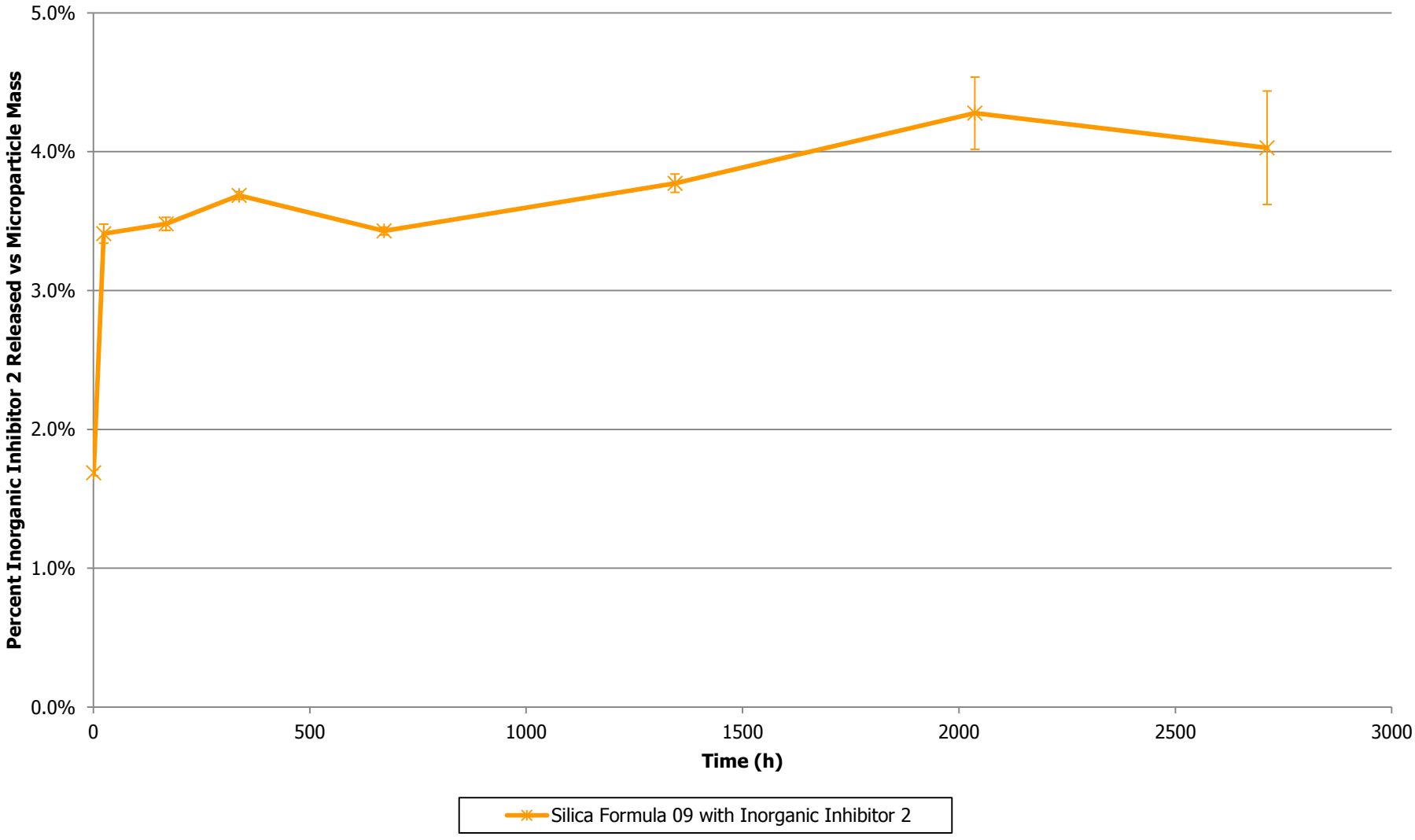
Inorganic: Short-Term Release



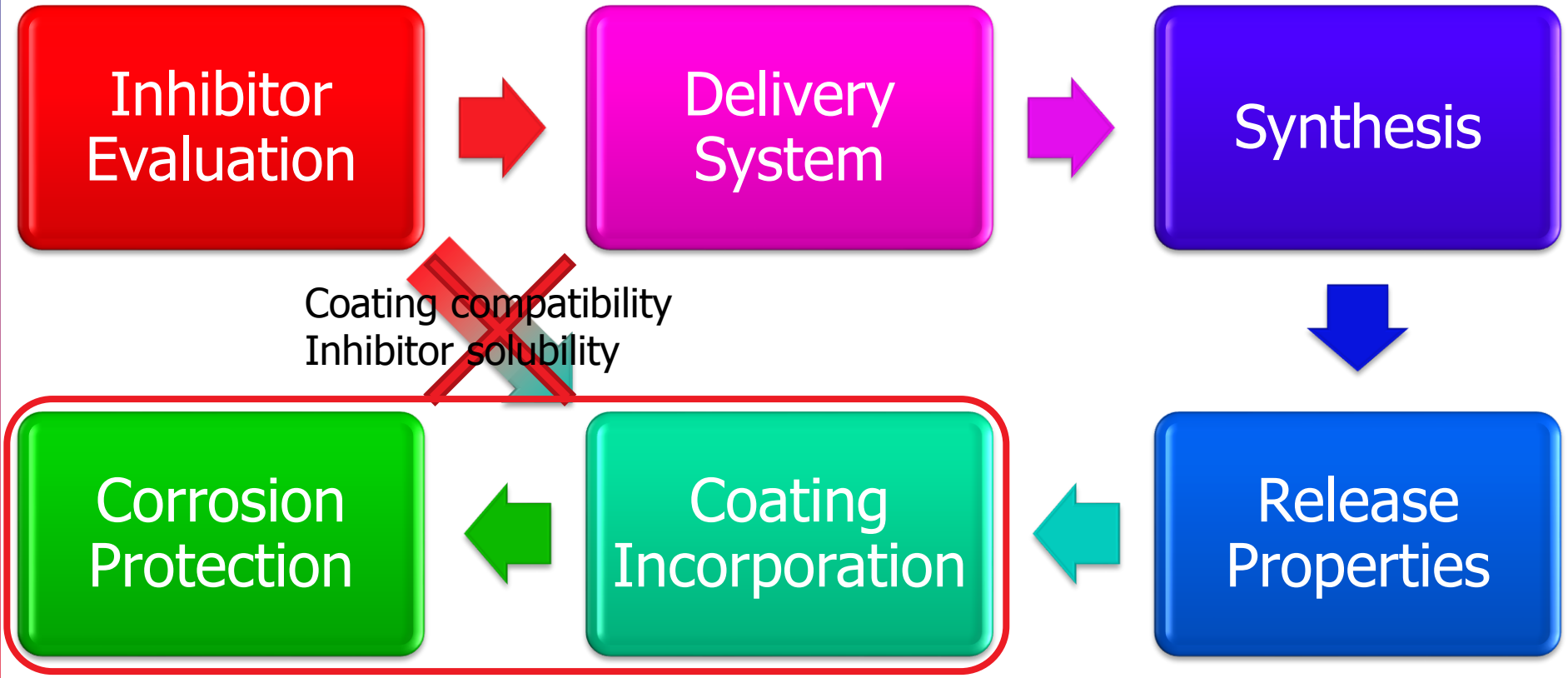
Inorganic: Long-Term Release



Inorganic: Long-Term Release

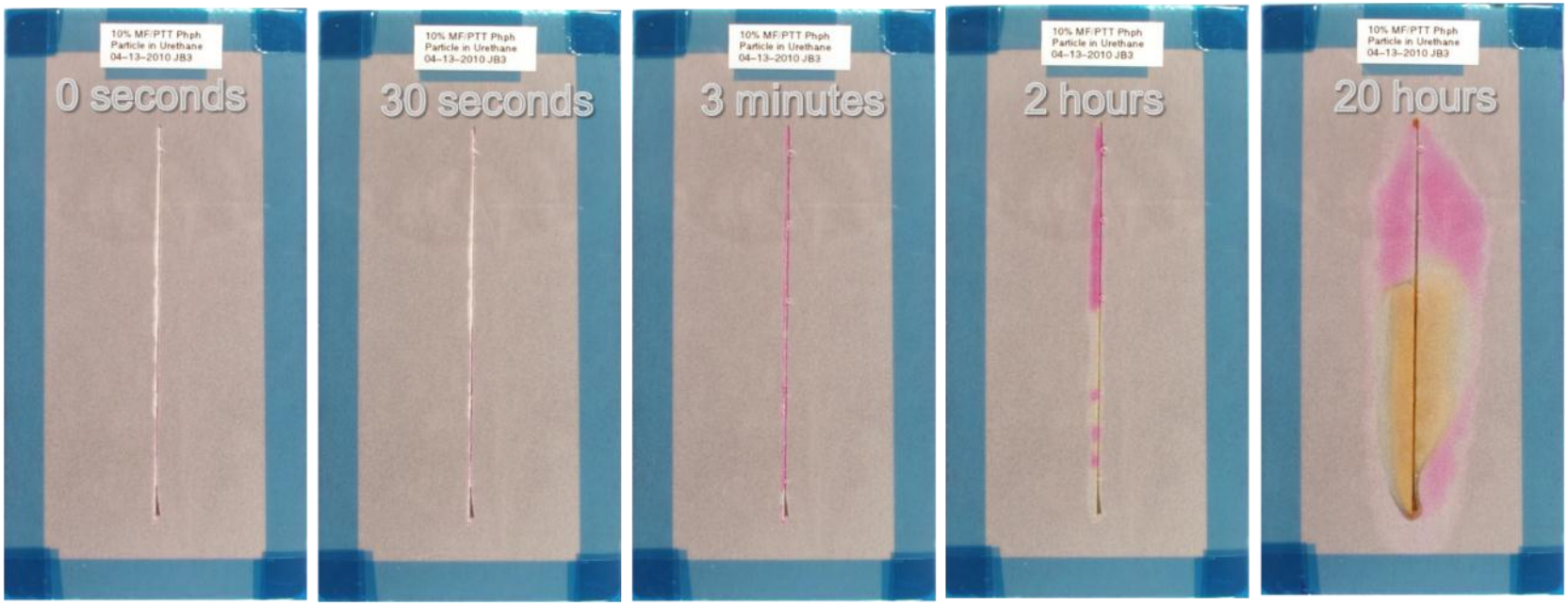


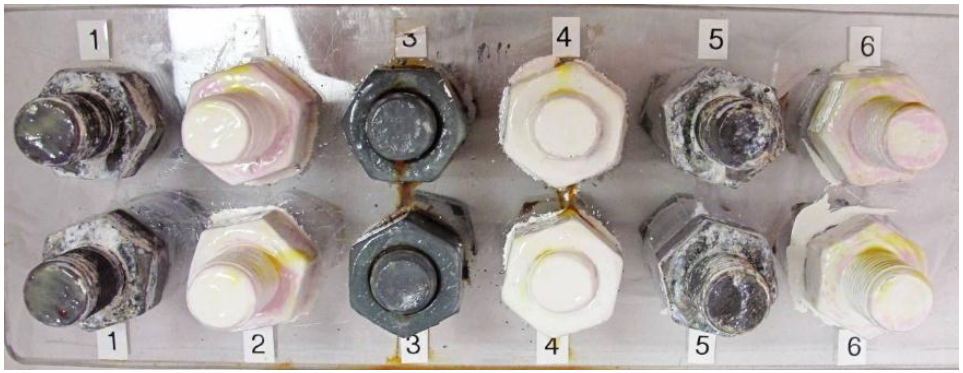
Delivery System

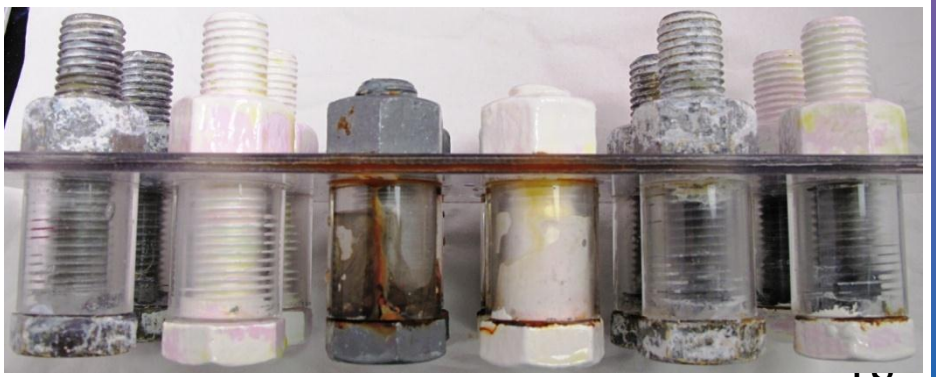


Corrosion Detection

Corrosion detection: 30s; Rust appearance: 2 h







Inhibition: Atmospheric Exposure

Carbon Steel; Commercial Coating; Atmospheric Exposure; 6.5 months

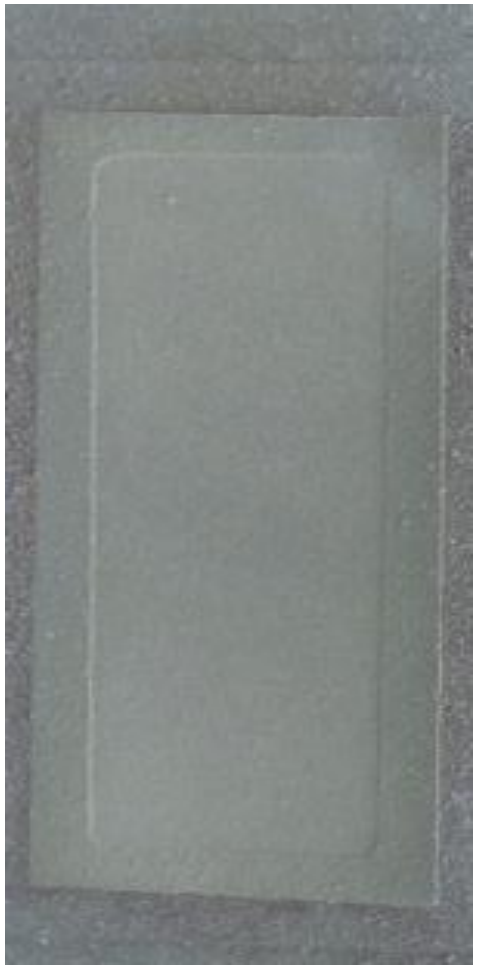
Commercial product with inhibitor

With KSC Inhibitor Microparticles

Inhibition: Inorganic Zinc

Carbon Steel; Inorganic Zinc Coating; Atmospheric Exposure; 9 months

Control



With KSC Inhibitor Microparticles

Inhibition: Coating Compatibility

Carbon Steel; Waterborne Acrylic Coating; Salt Fog; 790 hours

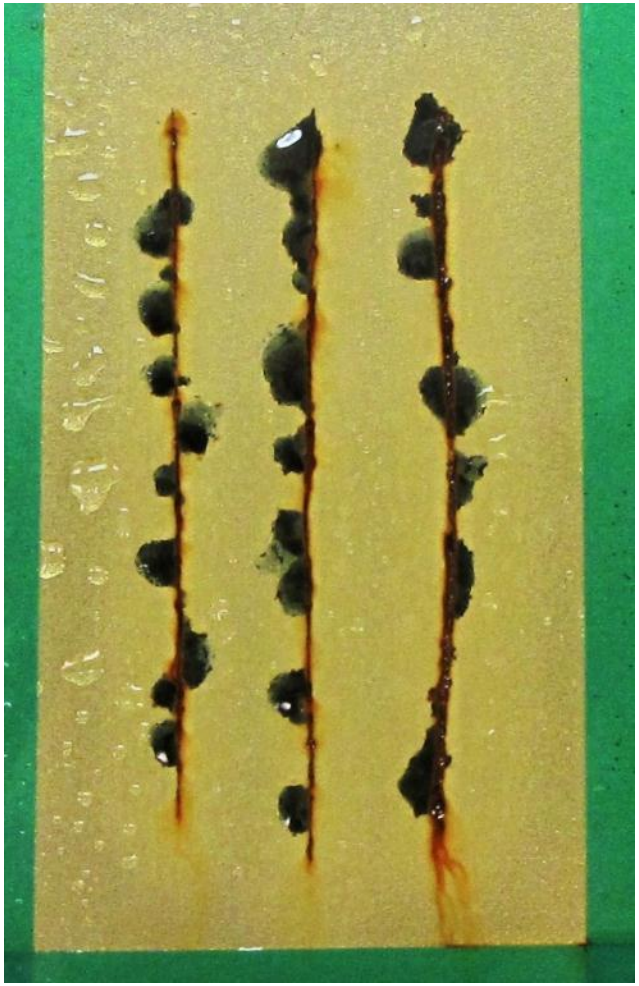
Control

Water soluble inhibitor

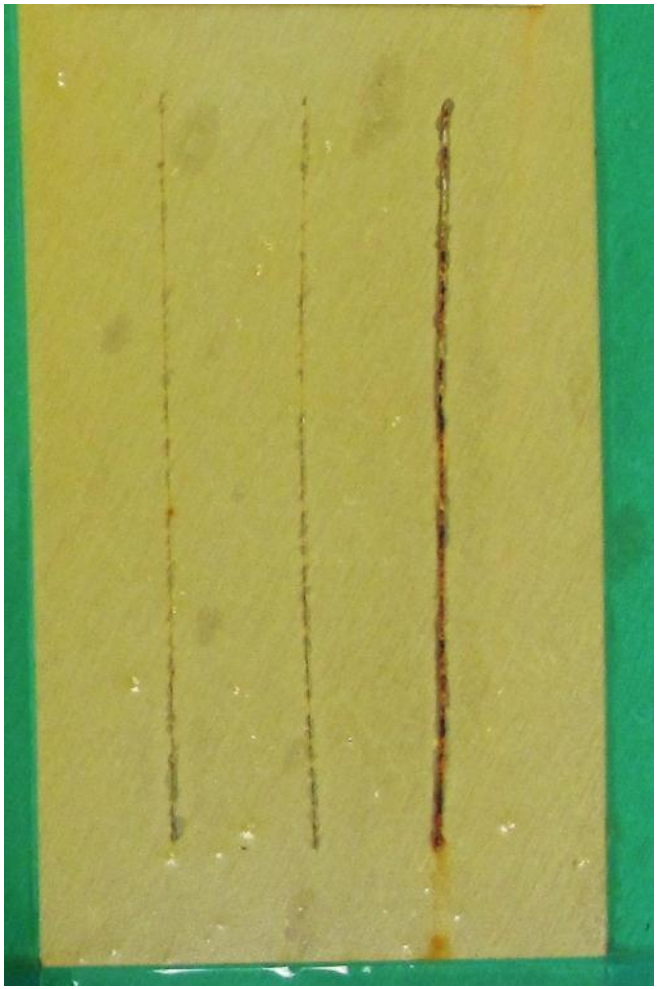
Silica-based particles with water soluble inhibitor

Self Healing Capsules

Carbon Steel; Epoxy coating; Salt Fog; 700 hours



Control



With KSC Self-healing capsules

Conclusion

- Corrosion protection of pure inhibitors and combinations measured through electrochemical and immersion testing
- Encapsulation of indicators, inhibitors and self-healing agents into organic and inorganic microparticles
- Short- and long-term pH controlled release
- Pigment grade particles are coating compatible
- Particles highly effective at detecting and preventing corrosion on demand

Acknowledgements

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